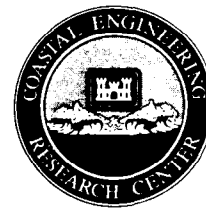




# Coastal Engineering Technical Note



## WAVE FORCES ON A WALL SHOREWARD OF THE STILL-WATER LINE

**PURPOSE:** To provide a revised method for calculating forces on a wall shoreward of the still-water line due to the runup of broken waves.

**GENERAL:** The Shore Protection Manual (SPM 1984), Section 7.III.4.b, presents an older method for determining wave forces on a wall shoreward of the still-water line. A need was recognized to update the method to incorporate the present state of knowledge on runup and surge forces. The method presented herein uses the results of Cross (1967) for determining forces due to a surge across dry ground, i.e., ground between the still-water line and the wall. A definition sketch is shown in figure 1.

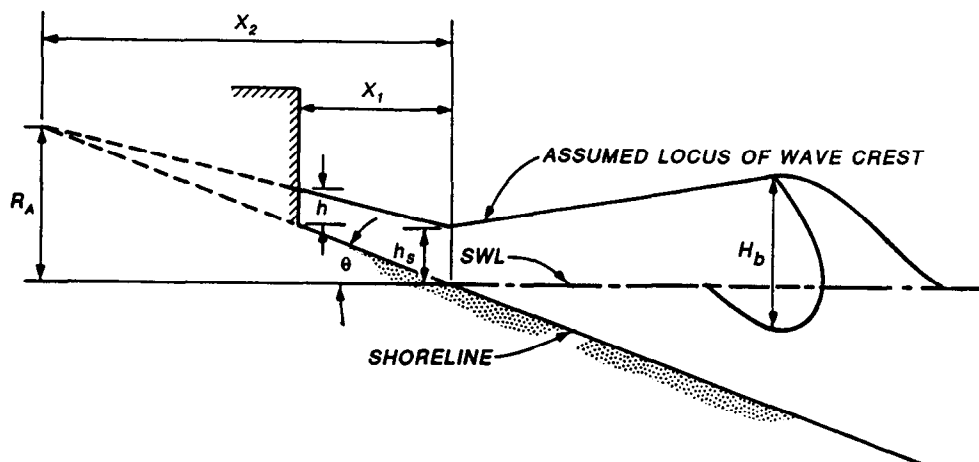


Figure 1. Wave pressure from broken waves: wall landward of still-water line.

**DETERMINATION OF WAVE FORCE:** The adjusted runup height,  $R_A$ , which would occur if the wall was not present can be estimated from Figure 2-3 and Table 2-1 in EM 1110-2-1614 (Equivalent to Figure 7-8 and Table 7-2 in the SPM). The Figure is for a slope  $S = 0.1$  where  $S = \tan \theta$  and

$$R_A = rR$$

$\theta$  is the angle of the slope,  $R$  is the runup height on a smooth slope from Figure 2-3 in the EM, and  $r$  is an adjustment coefficient from Table 2-1 in the EM.

Camfield (1991) shows that the breaking wave height above still water at the shoreline,  $h_s$ , can be approximated as

$$h_s = 0.2 H_b$$

The value of the surge height,  $h$ , at the wall is then given as

$$h = 0.2 H_b \left( 1 - \frac{x_1}{x_2} \right)$$

where  $x_1$  is the distance from the shoreline to the wall and

$$x_2 = \frac{R_A}{S}$$

The surge of the broken wave on the slope can be defined as shown in Figure 2.

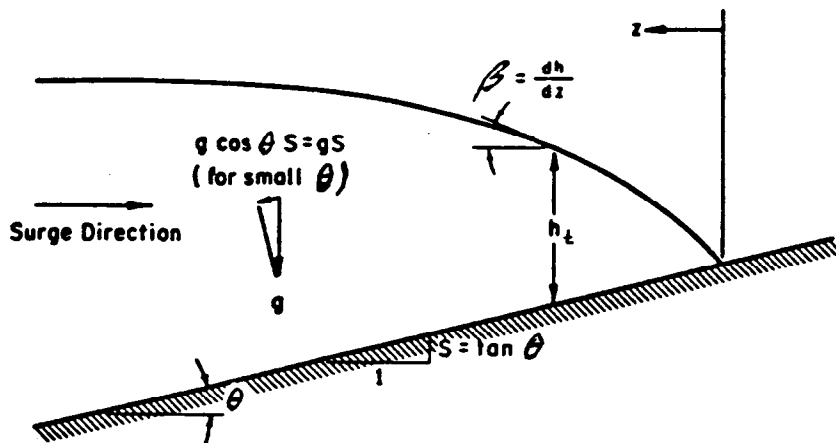


Figure 2. Definition sketch of surge on a dry bed (slope exaggerated).

Cross defined the force,  $F$ , per unit length of wall at any instant as

$$F = \frac{\rho g h_t^2}{2} + C_F \rho u^2 h_t$$

which represent a hydrostatic term and a dynamic term. The coefficient  $C_F$  as defined by Cross can be given as

$$C_F = (\tan \beta)^{1.2} + 1$$

where

$$\tan \beta = \frac{u^2}{C_h^2 h_t}$$

as shown in Camfield (1980),  $u$  is the velocity of the surge at any instant,  $C_h$  is the Chezy roughness coefficient, and  $h_t$  is the depth of the surge impinging on the wall at that instant. The dynamic portion of the force,  $F_d$ , is then

$$F_d = \left[ \left( \frac{u^2}{C_h^2 h_t} \right)^{1.2} + 1 \right] \rho u^2 h_t$$

Using the expression of Keulegan (1950) for the velocity,  $u$ , of a surge,

$$u = 2 (gh)^{1/2}$$

which results in

$$\frac{u^2}{C_h^2 h} = \frac{4g}{C_h^2}$$

and the total force,  $F$ , per unit length of wall is then

$$F = 1/2 \gamma h^2 + 4 \left[ \left( \frac{4g}{C_h^2} \right)^{1.2} + 1 \right] \gamma h^2$$

where  $\gamma$  is the specific weight of water. For any value of  $h$ , the dynamic term is at least eight times as large as the hydrostatic term. For most cases,  $30 < C_h < 100$ , so that as a simplified approximation

$$F \approx 4.5 \gamma h^2$$

or substituting in for  $h$ ,

$$F \approx 0.18 \gamma H_b^2 \left( 1 - \frac{x_1 S}{R_A} \right)^2$$

COMMENTS: Camfield and Street (1969) showed that maximum slope where waves will break is approximately  $\theta = 9^\circ$ , or  $\cos \theta = 0.988$ . The assumptions made are, therefore, considered reasonably accurate for all slopes where broken waves will surge across the shoreline. For further information contact Dr.

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EXAMPLE: A design wave is 3 feet high in deep water and has a period of 12 seconds. The breaking wave height is 6 feet. The waves cross a shoreline of cobbles with a slope  $S = 0.10$  and impact on a wall located 10 feet shoreward of the still water line. Find the force on the wall.

$$\frac{H_o}{gT^2} = \frac{3}{32.2 (12)^2} = 0.000647$$

$$\cot \theta = 10.0$$

From either the EM of the SPM,  $R = 1.6 h_o' = 4.8$  feet. Assuming a value of  $r = 0.80$  for large cobbles,  $R_A = 3.84$ . The force per foot length of wall is

$$F = 0.18 \quad 8H_b^2 \left( 1 - \frac{x_1 S}{R_A} \right)^2$$

$$F = 0.18 (64) (6)^2 \left( 1 - \frac{10 (0.10)}{3.84} \right)^2$$

$$F = 227 \text{ lbs/foot length of wall}$$

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